

To ascertain this, I put a block of concrete into distilled water, and on examining the water a week afterwards, I found a trace of lime in it. I then consulted Mr. Faraday, and he said that he thought it probable that there was a little uncombined lime, but that if I would wash it and suspend it in the river six months, he would then try it. I suspended a block in the river at Woolwich six months; I then took it up and let it soak for a week in distilled water, and there was not a single trace of lime in the water, showing that there is no chemical action of the water upon the hydraulic lime.

(*Sir Howard Douglas.*)—What do you think is the adhesive strength of concrete of the best material compared with that of stone, say York stone or Portland stone?—It depends upon what kind of power you use. As resisting a crushing power, I should think about a third or a fourth.

A concrete of blue lias lime and shingle, thrown into the water at Bridport Pier, without any precaution, "is now in such a state of solidity that it admits of being broken and polished, and it is as hard as any pudding stone, in fact nearly as hard as the flints of which it is composed."

Witness thought concrete would resist a crushing power of, probably, a ton on a square inch. Did not propose to use it where it would be exposed to mechanical action. Proposed to use the blue lias lime from Lyme Regis, being the nearest, cheapest, and, as he thought, the best. Was satisfied that blue lias lime would stand in salt water without the use of puzzolana or cement, but was not yet quite determined as to the most economical proportions. Was disposed to think it would be desirable to keep the blocks a year before they were put into the water.

*Mr. W. Cubitt*, engineer, being asked by the chairman if he had been in the habit of using concrete, replied:—

"I have done, as much in concrete within five miles of Dover as would almost form one face of this breakwater.

What is your opinion of its solidity?—I am of opinion that where you have a concrete very good it will stand a great deal of wear and tear. But I have also another opinion, that in that neighbourhood it is difficult to make concrete which is fit for this purpose without mortar of a peculiar quality. I built a sea-wall between Dover and Folkestone a mile in length, the deepest part of which is 70 feet from the base to the top, and every where in the face of that which was accessible to the sea I lined it with the very hardest brick I could find; and even that will not stand the wear and tear of the sea, for I have known them wear into holes, and then you have to cut out pieces and replace them. Where the sea and shingle have acted upon it, it is like scrubbing it out with a hard scrubbing brush.

Suppose the masses of concrete to be used to within three or four feet of low spring tides, do you think they would last long?—They would, for the upper surface lasts a long time, according to the goodness.

Do you consider that concrete of the best quality would be a suitable foundation for the wall in Dover Bay?—Yes, I should conceive that good concrete would; but I doubt whether you would get it; because I do not think, in the quantities there wanted, it is to be got. In the first place, there is no lime of the quality fit to make concrete for this purpose; for the only lime that is fit to be had in one place, that is, such lime as is being now used by Mr. Hartley, the engineer, at Liverpool."

This lime came from the Halkin mountains in North Wales.

*Mr. J. M. Rendel*, engineer, was disposed to recommend brickwork built in large masses with cement, and carried out and put in position. When asked the grounds of his recommendation, said:—

"The experience which I have had is rather from some experimental blocks made at Birkenhead. In a very early stage of our pro-

ceedings there last year I caused a number of brick piers to be built at about the level of low water, in order to test the goodness of the different kinds of mortar we were making, and those piers were constructed where every tide washed them. Two months after they had been set I had them knocked to pieces, and it was with the greatest difficulty, the cement being nothing more than good hydraulic lime mortar. They were columns of about 4 feet square and 8 feet in height. Some of those masses remained until about a week ago, when I caused them to be lifted by the upper courses, for which the adhesion of the mortar to the bricks was sufficiently strong, the mass being five to six tons, and quite solid, although, as I said before, they had been built very near low water, and, consequently, from the day they were built they had been exposed to the almost constant action of the sea."

These masses were 4 feet square by 8 feet high, and, taking them at 120 lbs. the cubic foot, weighed about six tons each. When asked what crushing power such masses would bear, said, the commissioners might infer it from the fact, that a chimney at Glasgow, which is 360 feet high, had never shown the slightest symptoms of crushing at the lower courses, although nothing more than common brickwork. Witness did not believe there was an instance upon record, where a wall had fallen from the crushing of the bricks.

He was asked the difference in weight between brick and concrete, and replied:—

"The heaviest concrete I have ever had an opportunity of weighing was about 138 lbs. to the cubic foot; now ordinary brickwork in cement will be about 120 lbs.

What is Portland stone?—About 140. Good concrete is about the weight of Portland stone; but then it requires the concrete to be very well made; and I doubt whether you could accomplish that weight in very large masses of concrete.

(*Captain Beaufort.*)—What is the weight of granite?—164, and limestone about 170, and Bath stone is about 132; but you may press bricks in making them, so that the masses of brickwork will be actually heavier than granite.

(*Captain Brandreth.*)—Would the expense be much increased by that?—I think the expense would be increased; it would be about 2s. or 3s. a thousand for the moulding.

(*Captain Washington.*)—Would you make those bricks by machinery?—No; I do not like machine-made bricks. We are making at Birkenhead now more than 60,000,000, and I find that good hand-made bricks, thoroughly well made, are better than those made by machinery."

As to concrete, witness said until he saw chimneys built of concrete as high as our brick chimneys, should have a preference for brickwork. "I cannot bring myself, as a practical man, to the opinion that masses of concrete can ever be made as sound as masses of brickwork; and for this reason, if I build a mass of brickwork, I can depend upon every part of it being equally sound; but I know no plan by which large masses of concrete materials can be so thoroughly coated with lime, as to obtain the same certain results."

"You would not recommend blocks of concrete as a substitute for stone for facing or building breakwaters?—No, I would not take the responsibility. I approve highly of its use in many kinds of foundations, but not when made in separate blocks, and employed in the construction of walls."

Said he would not use it in blocks for the foundation, even, of the Dover Breakwater.

Thought the price of the brick blocks would be about 27s. a cubic yard. Concrete for such a purpose must not have less than one-sixth of ground lime in its composition. Thought no lime so good for the purpose as the ordinary blue lias, which hardens earlier than the Halkin mountain lime. Blocks made of good hydraulic lime would go on hardening under water just as well as above. It must be kept above water to acquire sufficient solidity to bear moving.

*Mr. George Rennie*, engineer, objected to the "use of any artificial or inferior materials,

such as concrete" in any part of the breakwater. He said,—

"We find that almost all limes are soluble in water, except what they call hydraulic limes, and many of them also are subject to it; that is the experience of the French engineers. Since those works at Algiers began, I have talked with French engineers about them; the masses are dissolving, many of them.

(*Captain Brandreth.*)—What lime do they use?—They use a hydraulic lime, but it is not proof against this effect.

But we have limes that will not dissolve under water?—Yes, I think the lias lime stands remarkably well, and the Halkin lime; but General Pasley's experiments are very convincing upon that subject."

*Mr. Jesse Hartley*, engineer, considered that masses of brick put together with good cement would be as capable of enduring a crushing weight as blocks of limestone. Was not disposed to recommend concrete as wholly to be used. Considered the blue lime of Lyme Regis very inferior to the Halkin lime. Thought concrete, if it could be kept compact till it was set, the best thing that could be had for the foundation of any building, submarine or otherwise. Would rather use bricks than Portland stone, because Portland stone gets eaten by worms. Would use rough bricks rather than smooth, and to save time would introduce a little iron hooping.

*Mr. G. Godwin*, architect, had been led to give attention to concrete by offer of a medal by the Royal Institute of Architects.

"Your object was to see by your representations and statements of concrete if you could get the prize?—Exactly.

Did you succeed in getting the prize?—I did.

Do you know any sub-marine work of ancient date in which concrete was used?—I know of no actual work. We have instructions for the preparation of sub-marine foundations of concrete by Vitruvius and by writers of more recent date, Alberti, Philibert de l'Orme, Belidor, &c.

Do you think it fully ascertained that in ancient times concrete was used for the foundations of the greatest buildings?—I do; concreted masses are found in Mexico, and in Egypt, and in Greece, and even more so in Rome. Stuart and Revett speak of some part of the Propylæa at Athens as being of concreted work, and say it is almost impenetrable."

He considered that well made concrete increases in solidity and hardness by age, and in time assimilates to rock. Thought, when exposed alternately to wet and dry, that frost had an effect upon it, the more so, as in practice it is seldom allowed to solidify properly before being exposed to the action of the water. Believed there was, amongst architects and builders, a general confidence in the use of concrete for foundations of buildings. The new houses of Parliament stand on a bed of concrete. Concrete and York landings were, he believed, introduced under the London Custom-House, when the original foundation failed. Had never heard of its failure in the position of a foundation.

(*Chairman.*)—As you have given more attention to the subject than any other person in this country, what is your opinion as to the solidity and durability of well-made concrete?—I must not claim that character; I have given a good deal of attention to it, but there are gentlemen who have given much more;—as far as my investigation goes, for foundations, I think there can be nothing better.

Do you mean foundations on land, or do you mean to include foundations in deep water in the sea?—Foundations in deep water also, when made with hydraulic lime, and properly laid."

"Do you think blocks of concrete, 10 feet long, 5 feet wide, and 3 feet thick, made with the best hydraulic lime, may be relied upon for